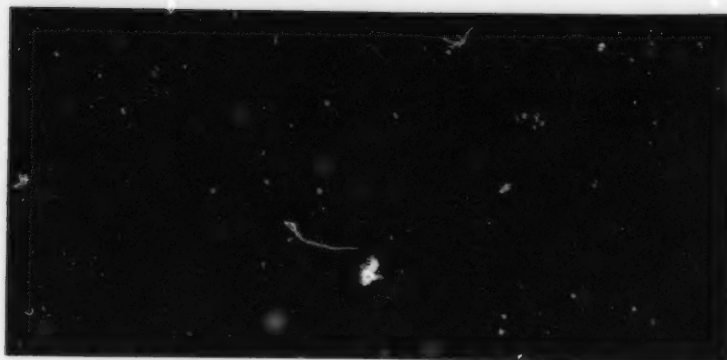




CA1
DTC800-
89
063

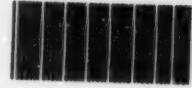


CA1
DTC800-
89
063

444728

M

41.D



**Optimization of Hull Form
for
Future Arctic Tankers
Phase I**

**Summary Report
TP 10186E**



**Prepared for
Transportation Development Centre
Policy and Coordination Group
Transport Canada**

**Prepared by:
M. Luce
D. Baker
A. Sneyd
A. Taylor
Canarctic Shipping Company Limited
1005-350 Sparks St.
Ottawa, Ontario
K1R 7S8**

September 1989

444728

DISCLAIMER

The contents of this report reflect the views of the authors and not necessarily the official views or policies of the Transportation Development Centre of Transport Canada.

PROJECT TEAM

For Canarctic Shipping Company Limited

M. Luce
D. Baker
A. Sneyd
A. Taylor

ACKNOWLEDGEMENTS

The author wishes to acknowledge the help and guidance of all those individuals who have contributed to the success of this project, in particular; Mr. Tom Peirce, Transportation Development Centre, Dr. Bruce Colbourne and Mr. Terry Lindstrom of the Institute for Marine Dynamics (IMD) in St. John's, Newfoundland.

LANGUAGE NOTICE

Un rapport sommaire en français de ce document est également disponible.



1. Transport Canada Publication No. TP 10186E		2. Project No. 7114		3. Recipient's Catalogue No.	
4. Title and Subtitle Optimization of Hull Form for Future Arctic Tankers - Phase I Summary Report				5. Publication Date September 1989	
				6. Performing Organization Document No. CSL - 8 - 5901	
7. Author(s) David Baker et al.				8. Transport Canada File No. D 1460-261	
9. Performing Organization Name and Address Canarctic Shipping Company Limited 1005 - 350 Sparks St. Ottawa, Ontario K1R 7S8				10. DSS File No. 57SZ.T8200-8-8506	
				11. DSS or Transport Canada Contract No. T8200-8-8506/01-SZ	
12. Sponsoring Agency Name and Address Transportation Development Centre 200 René Lévesque Blvd. West West Tower, Suite 601 Montreal, Quebec H2Z 1X4				13. Type of Publication and Period Covered Summary	
				14. Project Officer T.H. Peirce	
15. Supplementary Notes (Funding programs, titles of related publications, etc.) This project was funded, in part, by Task 6.6 of the Energy Research and Development Program. A summary of main report TP 10045E (Protected).					
16. Abstract This report describes the development of a tanker hull form suitable for operation 80% of the time in open water and 20% in ice. The hull form has been developed in a number of steps including: a review of the potential environmental conditions, the input from five Canadian Arctic ship designers with respect to overall hull configuration, the development of a transit simulation that included capital and operating costs, physical model testing and numerical performance prediction. The optimizing criteria for the design was elected to be the required freight rate. The results from the work have resulted in a 110,000 DWT ice capable tanker. The level ice performance of the hull is considered to be comparable with modern arctic hull designs however the physical model tests indicated that the ship did not manoeuvre as well as may have been expected. This area is subject to review by a continuation of this work.					
17. Key Words Arctic, icebreaking hullform, model tests, hullform design, optimization,			18. Distribution Statement Limited number of copies available from the Transportation Development Centre		
19. Security Classification (of this publication) Unclassified		20. Security Classification (of this page) Unclassified		21. Declassification (date) -	22. No. of Pages vi, 12
				23. Price -	

1. N° de la publication de Transports Canada TP 10186E	2. N° de l'étude 7114	3. N° de catalogue du destinataire		
4. Titre et sous-titre Optimization of Hull Form for Future Arctic Tankers - Phase I Summary Report		5. Date de la publication septembre 1989		
		6. N° du document de l'organisme exécutant CSL - 8 - 5901		
7. Auteur(s) David Baker et al.		8. N° de dossier - Transports Canada D 1460-261		
9. Nom et adresse de l'organisme exécutant La compagnie Canarctic limitée 350, rue Sparks Suite 1005 Ottawa (Ontario) K1R 7S8		10. N° de dossier - ASC 57SZ.T8200-8-8506		
		11. N° de contrat - ASC ou Transports Canada T8200-8-8506/01-SZ		
12. Nom et adresse de l'organisme parrain Centre de développement des transports 200 ouest, boul. René-Lévesque Tour ouest, suite 601 Montréal (Québec) H2Z 1X4		13. Genre de publication et période visée Sommaire		
		14. Agent de projet T.H. Peirce		
15. Remarques additionnelles (Programmes de financement, titres de publications connexes, etc.) Ce projet était subventionné, en partie, par le 6.6 du Programme de R&D énergétiques. Sommaire du rapport final TP 10045E (Protégé).				
16. Résumé Ce rapport décrit la recherche sur une forme de coque pouvant convenir à un navire-citerne devant naviguer 80 p. 100 du temps dans des eaux libres de glaces et 20 p. 100 dans des eaux chargées de glaces. La recherche a passé par les étapes suivantes: tour d'horizon des conditions environnementales possibles, avis de cinq grands bureaux d'architectes navals canadiens concernant la configuration globale de la coque, mise au point d'un modèle de simulation tenant compte des coûts d'immobilisation et d'exploitation, essais sur maquette et prévisions numériques des performances. L'optimisation de la forme a été faite en fonction d'un critère déterminant: le coût du transport. La recherche a débouché sur une forme de coque pouvant convenir à un navire-citerne de quelque 110 000 tonnes de port en lourd, dont les performances dans des glaces uniformes sont comparables à celles d'une coque moderne de type arctique. Mais les essais sur maquette ont montré que sa pilotabilité n'est pas aussi bonne que prévu. C'est dans ce secteur que le rapport recommande de poursuivre la recherche.				
17. Mots clés Arctique, forme de coque arctique, essais sur maquette, conception de coque, optimisation.		18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.		
19. Classification de sécurité (de cette publication) Non classifiée	20. Classification de sécurité (de cette page) Non classifiée	21. Déclassification (date) -	22. Nombre de pages vi, 12	23. Prix -

Table of Contents

	<u>Page</u>
1. INTRODUCTION	1
2. HULL FORM REVIEW	2
3. ICE DATA ANALYSIS	5
4. PRELIMINARY PERFORMANCE PREDICTION AND EVALUATION . . .	7
5. HULL FORM DESIGN	8
6. PHYSICAL AND NUMERICAL MODEL TESTING	8
7. FULL SCALE PERFORMANCE PREDICTION	9
8. CONCLUSIONS	10
9. RECOMMENDATIONS	11

1.0 Introduction:

Over the last decade a number of hull design concepts for arctic class vessels have been developed and operationally evaluated in the Canadian Arctic.

Invariably, such concepts have been confined to small vessels with a specialized and restricted local role. There is a need to evaluate these concepts in terms of the large ice breaking hull forms which will be required for future generation arctic tankers. This will also provide the opportunity to apply the current advanced knowledge of the arctic operating environment and its impact on vessel operations to a fully Canadian design for future arctic tankers.

It is believed that the most efficient way to develop the design expertise necessary to satisfy this future need is to develop two representative hull forms. Both hull forms will be approximately 110,000 tonne deadweight ships but will have significantly different operating criteria. The first ship, designated the 20/80 ship, will be designed to operate 20 percent of the time in ice and 80 percent in open water. The second ship, designated the 80/20 ship, will be designed to operate 80 percent of the time in ice and 20 percent of the time in open water.

This report describes the design development of the first hull form although research and development work, as appropriate, has been completed on both hull form designs.

2.0 Hull Form Review

Prior to starting the design of the 20/80 ship the operating and overall hull design criteria were reviewed. This review resulted in a series of environmental and design criteria that were then used in the subsequent design. These criteria may be summarised as;

a) Ship Criteria

Length	300 m (maximum)
Beam	Unrestricted
Depth	Unrestricted
Icebreaking Draught	12.0 to 15.3 metres
Deadweight	105,000 - 110,000 tonnes

b) Performance Criteria

Calm Water Speed	- 14 knots
Rough Water Speeds	- 10 knots in bow seas (Beaufort Wind Force 8)
	- 12 knots in beam seas (Beaufort Wind Force 9)
Level Ice:	- 2 knots ahead in 1.2m of level ice (500 kPa)
	- 2 knots astern in 1.0 m level ice
	- ease of extraction from 10 knot ram
	- 6 knots astern in a broken channel
	- 2 nm steady turning radius in 1.0 m level ice

c) Environment Criteria - Ice

The ship is assumed to operate 80 percent of the year in open water and 20 percent of the year in ice. The ice environment will be predominantly first year ice with only trace amounts of old ice. The maximum ice is 1.2 m with

full winter strength achieved in late March with significant warming and reduction of strength by late April. It is assumed that a snow cover of 0.3m will occur over all regimes.

d) Environment Criteria - Open Water

The ship will spend 80 percent of its time in an open water environment typical of the North Atlantic, with maximum seastates of Beaufort 8.

Following the definition of the design criteria a "State of the Art" report was completed that included direct input from five Canadian Arctic ship designers.

The conclusions from the "State of the Art" report included recommendations on both hull form design and performance prediction procedures. The hull form recommendations resulting from this work were;

- a) The ship should have a modern but smooth bow shape ie, without chines or reamers with a bollard pull per metre of beam of about 6.5 tonnes/m.
- b) The ship should have an L/B ratio of 5.5 to 6.5. This is very similar to standard open water ships and is only slightly higher than the equivalent ratio for a pure icebreaker.
- c) The ship should have a midbody shape with vertical sides and parallel length, both features guided by the need for low construction cost.
- d) The ship should have a conventional stern shape forward of the propeller but with an ice deflecting shape above the

rudder. The rudder should also be protected by a horn, and the rudder stock and steering gear protected by rudder stops.

- e) The ship should have a single ducted propeller.
- f) The outer shell below the waterline should have a low friction coating.
- g) A waterwash system should be installed in the bow.

The overall conclusion from the report was that, with careful attention given to the bow and stern shape, a large commercial ship can operate very efficiently in both ice and open water regimes.

The performance prediction recommendations resulting from this review indicated that both full scale and model scale data should be used to develop the final performance prediction.

The optimization of a hull form may be developed based on any number of criteria, for example ice resistance, open water performance, building costs, etc. Following a brief review of the available options that would satisfy the overall objective of the project, it was decided to use the Required Freight Rate (RFR) per tonne of cargo. This parameter included all aspects of the ship performance, hull construction, capital costs, operating costs and provided an effective optimizing criterion.

Based on this decision, an existing performance evaluation computer model (TRANSIM) was modified and used to evaluate the prototype hull forms.

The input variables to the model included the ship principle particulars, shipbuilding costs, the proposed shipping route and

performance predictor equations for both open water and ice conditions.

The output is the RFR based on the calculated capital cost, the interest rates, the operating costs and the ship performance.

A summary of the conceptual design and methodology is presented in point form below.

a) Hull Form

- Conventional bow form
- Stem Angle 20 to 23 degrees
- L/B ratio from 5.5 to 6.5
- No midbody flare
- Nozzle
- Single screw
- Conventional rudder
- Option of passive and/or active performance enhancing system

b) Performance Prediction Methodology

- Full scale data in conjunction with numerical analysis
- Model test data, substantiated with model/full scale correlation.

c) Selection of Evaluation Procedure

- Modified 'TRANSIM' program developing a 'Required Freight Rate' that is used as the optimizing criterion.

3.0 Ice Data Analysis

The environmental criteria defined as part of the design criteria, discussed in section 2, was generated by Canarctic from

their operating experience in the Arctic. In order to more clearly define the environment Norland Science and Engineering Ltd. (Norland) and the National Research Council (NRC) were commissioned to undertake a literature review, an analysis of the available ice data and any environmental criteria that could be used in the development of the hull design. The report assumed that the area of most interest was Baffin Bay.

The review concluded that a reasonably good set of level first year ice thickness data exist for most seasons and many areas in the Canadian Arctic. The majority of data was collected for landfast ice conditions. However very little information on ice properties was found for Baffin Bay perceived as being the primary ice operations area of the proposed 20/80 ship.

The review also determined that it was not possible to obtain ice property data directly from the analysis and interpretation of SAR imagery. SAR imagery may be used only for the identification of ice types and, with some qualifications, for the identification of level vs. rough ice as it relates to ship performance. Ice properties could be inferred by drawing on a knowledge based of data for each level first-year ice type. However, the present ice properties knowledge base is very limited, has many gaps and is not well tied to historical SAR imagery. Other remote sensing systems besides SAR have potential to directly measure a limited number of ice properties. The impulse radar and electromagnetic techniques could be used to measure ice thickness. The infrared line scanner could measure surface temperature of either the snow free ice surface or snow cover. These systems are presently in various stages of development and validation of their outputs will be required for this application.

4.0 Preliminary Performance Prediction and Evaluation

The results of section 2 indicated that a performance prediction and evaluation procedure should be adopted that incorporates full scale data and a full range of construction and operating cost variables. To accomplish this it was recommended to use a modification of an existing model "Transim". The model consists of a number of elements including a ship performance prediction and transit simulation.

The performance prediction technique is based on the performance of existing "reference" ships and a series of algorithms which are used to predict the performance of a prototype ship by adjusting the performance of selected reference ships to the performance of the prototype ship as a function of ship parameters.

Using these relationships it is possible to modify an existing icebreaker's known performance to the performance of a prototype ship with a different friction coefficient, bow form, thrust and beam. The program includes both ice and open water algorithms.

The Transit Simulation component of TRANSIM evaluates the economics of a commercial Arctic Class ship. The model uses a set of ship operating criteria and environmental data to simulate the performance and economic aspects of an ice transitting ship design. The evaluation includes all ship operating and construction costs to generate a complete operational simulation of a particular voyage through the defined ice regime.

5.0 Hull Form Design

Using the ship criteria developed as part of section 2, and the performance prediction and evaluation techniques developed in section 4, it is possible to develop parametric relationships between the hull form's primary dimensions and the optimizing criteria, the Required Freight Rate (RFR).

The variables that were adjusted to optimize the hull design were included Length, Breadth, Depth, Block Coefficient and Kashteljan Coefficient. Although all of the variables within 'TRANSIM' can be adjusted by the user, with the objective of establishing an optimum hull form based on the 110,000 tonne tanker, a number of these variables were fixed for this application.

Based on this approach, variables the Transim program was used over a range of L/B ratios to establish the relationship between the primary hull form variables, length and beam and the Required Freight Rate (RFR).

6.0 Physical and Numerical Model Testing

Based on the results of the hull form design analysis in section 5 the selected hull form was model tested at the Institute for Marine Dynamics (IMD) open water and ice tank facility in St. John's Newfoundland. The model was constructed to a scale of 1:35. The model was tested at two draughts, equivalent to 12.0 m and 15.3 m.

The model tests simulated a range of ice thickness from 0.7m to 1.5m full scale. The test speeds were selected to represent and extend beyond, the maximum proposed capability of the ship. This would permit the final performance prediction to be an interpolation of model test data and not an extrapolation. Presawn ice tests were

conducted in all the tests at identical speeds to the conventional level ice resistance tests with the exception of two ice sheets. Following the level ice resistance tests in those two sheets, the model was used to assess the channel breakout capability of the hull.

Two data analysis procedures were adopted in the report, namely; a non-dimensional analysis developed by the Institute for Marine Dynamics (IMD) and a discreet analysis of each data point.

The visual observations from the tests resulted in the general opinion from the operators present that, although the bow form appeared to perform well, the stern form did not. The primary reason for this was considered to be fullness and length of the stern form which did not permit the vessel to achieve any appreciable yaw angle in the broken track. This resulted in the bow form not being able to effectively come into contact with the channel edge.

Clear water Resistance, Self Propulsion and Overload tests were performed on the model at two draughts. In addition open water tests were conducted on the propeller/nozzle combination.

The sea keeping characteristics of the hull form were analyzed using the computer program "SHIPMO". This is a ship motion prediction program developed by the Defence Research Establishment Atlantic (DREA) and is widely used for sea keeping analysis.

7.0 Full Scale Performance Prediction

The proposed 20/80 hull form was the subject of both numerical and physical model testing. The primary focus of the work was the level ice performance, although open water performance and sea keeping were also investigated.

The result of the analysis was a full scale performance prediction indicating that the desired vessel performance could be achieved with a power level of about 16.2 MW.

8.0 Conclusions

The objectives of the Hull Form Optimization project were to develop an optimum large commercial oil tanker hull form. This has been accomplished through a series of tasks that have included;

- a) A review of current Arctic Ship Design technology.
- b) The definition of typical Arctic environment.
- c) The Refinement of a transit simulation model.
- d) Refinement of a performance prediction methodology.
- e) Integration of the performance prediction into the transit simulation model.
- f) Use of the transit simulation model to develop an optimum hull form.
- g) Physical model tests of a selected hull form.
- h) Final selection and full scale performance prediction of the selected hull form.

The results of this work have demonstrated that the design of a 20/20 vessel can be accomplished using the methods discussed above. The two most important features of the design were shown to be the operating criteria, which include the port time and associated manoeuvring time and the necessity to carry fully segregated ballast, on a ballast draught of 12.0.

With respect to manoeuvring, the model tests did tend to indicate that the stern form was too full to effectively contributed to the ship turning. As a result, the ship was slower to manoeuvre and will take additional time in port turn rounds. The fullness of the stern is due to the requirement for a large block coefficient selected to

maximize cargo deadweight. Reducing the block coefficient to improve the stern will affect on the overall performance of the hull.

9.0 Recommendations

There are a number of recommendations that flow from this work:

- a) The stern form of the proposed hull is not considered to be sufficiently effective during manoeuvring. Additional work is necessary to improve the design whilst not significantly influencing the block coefficient of the final hull form.
- b) The limited physical manoeuvring tests conducted on the model did not provide sufficient information to support informed design modifications to the hull. It is considered that additional work is necessary with both the physical and numerical techniques to define the critical variables that control manoeuvrability.
- c) The 'Transim' Program has been shown to be effective in developing trends between primary hull variables and a selected optimization criteria. However, the program does have limitations associated with the definition of the environment and definition of operating criteria. There is clearly a need for developing a more rigorous approach to defining the environment with respect to ship performance and operating considerations.
- d) The performance of the subject hull has been evaluated in level first year ice. Additional work is necessary to expand this evaluation to include first year non-level ice regimes that will include, for example, mobile ice floes, pressure situations, rubble fields, ridges and rafting.

- e) The hull form design has been based on a tanker configuration. Broad assumptions were made with respect to the volume of the hull envelope that would be necessary to support the segregated ballast and other tanker regulations. Additional work should be completed to develop a preliminary tank plan and overall general arrangement of the ship.